Reduction and Association of the Scaphoid and Lunate: A Functional and Radiographical Outcome Study

William R. Aibinder, MD[1]   Ali Izadpanah, MD[2]   Bassem T. Elhassan, MD[1]

[1] Mayo Clinic, Rochester, Minnesota
[2] University Hospital of Montreal, Montreal, Quebec, Canada

Address for correspondence Bassem T. Elhassan, MD, Mayo Clinic, 200 First Street SW, Rochester, MN 55905 (e-mail: Elhassan.bassem@mayo.edu).

Abstract

Background   Management of scapholunate (SL) ligament disruption is a challenging problem. The reduction and association of the scaphoid and lunate (RASL) procedure has been described with varying results. This study assessed the outcomes of the RASL procedure.

Purpose   The objective of this study was to assess the outcomes of patients undergoing the RASL procedure at our institution in regard to pain relief, range of motion, radiographic and functional outcomes, complications, and reoperations.

Materials and Methods   Twelve patients with symptomatic chronic SL instability underwent the RASL procedure. The mean age was 35 years. The mean time from injury to surgery was 40 weeks. The mean follow-up was 89 months. Outcomes included visual analog score for pain, wrist range of motion, grip strength, and Mayo Wrist Scores. Preoperative and postoperative radiographs were reviewed.

Results   Pain scores improved in 10 wrists. Range of motion and grip strength worsened. The average Mayo Wrist Score was 63.3. The mean SL diastasis and angle improved, but seven wrists developed progressive degenerative changes, with two requiring a salvage procedure. Symptomatic progressive screw lucency occurred in eight wrists requiring screw removal.

Conclusion   The RASL procedure can improve SL widening but has a high rate of early failure and reoperation. Following reoperation, long-term follow-up demonstrates reasonable long-term durability in some cases.

Level of Evidence   This is a Level IV, therapeutic case study.

Keywords
► scapholunate
► RASL
► carpal instability
► reduction and association
► advanced collapse
► SL injury

Operative treatment of scapholunate (SL) ligament disruption is often recommended to decrease pain and prevent a predictable degenerative progression to SL advanced collapse (SLAC).[1] Multiple procedures have been described in the literature, including ligament reconstruction,[2,3] dorsal ligament capsulodesis,[4,5] and carpal arthrodesis.[6,7]

In 1997, Rosenwasser et al described the reduction and association of the scaphoid and lunate (RASL) procedure, which aims to achieve a pseudoarthrosis between the scaphoid and the lunate.[8] Initial reports demonstrated positive results at short- and midterm follow-up.[8,9] An arthroscopically assisted technique was described by Aviles et al.[10] Subsequent outcome studies, however, have demonstrated poor results with an inability to maintain radiographic reduction of the scaphoid and a high reoperation rate.[11–14]

The objective of this study was to assess the outcomes of patients undergoing the RASL procedure at our institution in regard to pain relief, range of motion, radiographic and functional outcomes, complications, and reoperations.

Materials and Methods

After Institutional Review Board approval, we conducted a retrospective review of patients undergoing the RASL procedure at our institution between January 1, 2000, and December 31, 2013. Twelve patients (12 wrists) were identified. Mean clinical follow-up was 24 months. Due to the referral nature of our practice, attempts were made to contact patients to obtain pain scores, activity level, and the Disabilities of the Arm, Shoulder, and Hand (DASH) scores. This increased the mean follow-up to 89 months (range: 7–203). Only one patient had less than 24-month follow-up and is discussed separately in the Results section. The mean age at surgery was 35 years (range: 17–62). The cohort included eight (67%) males and the dominant extremity was involved in eight (67%) cases. The indication for surgery was SL dissociation with pain and the absence of radiocarpal arthritis. One patient had an evidence of SLAC stage I disease, whereas the remainder had no evidence. This was determined based on preoperative radiographs; in cases where patients underwent a diagnostic arthroscopy preoperatively, the lunocapitate joint was assessed under direct visualization.

Six (50%) wrists demonstrated signs of dynamic instability (►Table 1). Three (25%) wrists underwent surgery using the arthroscopically assisted technique.[10,14]

Surgical technique for the arthroscopically assisted RASL was performed as described by Aviles et al.[10] A radial styloidectomy was not performed. For the open RASL, the procedure was performed similar to that described by Larson and Stern.[11] A ligament-sparing dorsal capsulotomy was performed to facilitate dechondrification of the SL articulation in all cases. Excision of a small portion of the radial styloid was performed in three cases to improve screw trajectory, which was performed under fluoroscopic guidance. A TriMed headless compression screw (TriMed, Santa Clarita, CA) was used in six

wrists, an HBS screw (BioPro, Port Huron, MI) was used in two wrists, a Herbert/Whipple screw (Zimmer, Warsaw, IN) was used in three wrists, and a TwinFix compression screw (Stryker, Kalamazoo, MI) was used in one wrist.

Postoperatively, patients were placed into a thumb spica cast for a period of 4 to 6 weeks before being transitioned into a removal splint. At this time point, active range-of-motion exercises were initiated. After a period of approximately 6 to 12 weeks, patients were instructed on a gentle strengthening program.

Clinical and functional outcomes included wrist range of motion, grip strength, Mayo Wrist Scores, which are reported when clinical follow-up with range of motion is available, and DASH scores, which are reported when available based on patient communication. Preoperative and postoperative wrist radiographs were reviewed. The SL interval, SL angle, implant loosening, and Watson SLAC classification were assessed.[1] The definition of Larson and Stern for radiographic success was used: SL diastasis less than 3 mm, an SL angle between 30 and 70 degrees, and no progression of arthrosis based on SLAC classification.[11] Screw position was also assessed on postoperative radiographs. On the lateral wrist radiographs, the ratio of the distance from the center of the screw to the dorsal and volar cortices defined the position of the screw (►Fig. 1). Complications and reoperations were also reviewed.

Data were reported as means and ranges for continuous data. Comparisons of nonparametric data were performed using Wilcoxon's rank-sum tests.

Results

Clinical Outcomes
The mean visual analog score (VAS) for pain decreased from 6.2 to 3.1, with improvement noted in 10 of 12 wrists (83%)

Table 1 Clinical, radiographic, and functional outcomes of patients

Patient	Gender	Age	Technique	Post-operative SLAC stage	Pre-operative SL gap (mm)	Post-operative SL gap (mm)	Pre-operative SL angle	Post-operative SL angle	Final ROM (extension/flexion)	Final grip (% contra-lateral)	Post-operative Mayo Wrist Score
1	M	22	Open	–	3[a]	1.4	49 degrees	73 degrees	60/45 degrees	79	70
2	M	26	Open	–	7	1.3	50 degrees	54 degrees	70/45 degrees	65	75
3	M	62	Open	III	4.5	4	55 degrees	57 degrees	45/30 degrees	100	65
4	M	39	Open	II	4.4	2.7	42 degrees	35 degrees	45/15 degrees	44	65
5	F	18	Open	–	1.1[a]	1	32 degrees	35 degrees	75/75 degrees	100	60
6	M	46	Open	III	6.9	4.9	77 degrees	62 degrees	46/70 degrees	40	95
7	M	41	Open	II	6.3	3	89 degrees	60 degrees	60/25 degrees	70	50
8	M	41	Open	II	2.5[a]	4	62 degrees	49 degrees	20/20 degrees	62	80
9	M	17	Open	–	3[a]	1.6	51 degrees	25 degrees	37/34 degrees	84	45
10	F	53	Arthro-scopic	II	4.1	3.7	32 degrees	52 degrees	70/55 degrees	63	55
11	F	25	Arthro-scopic	–	3[a]	1.7	72 degrees	65 degrees	30/20 degrees	75	40
12	F	28	Arthro-scopic	II	2.5[a]	2.5	38 degrees	51 degrees	50/40 degrees	57	60

Abbreviations: ROM, range of motion; SL, scapholunate; SLAC, scapholunate advanced collapse.
[a]Denotes patients with dynamic instability.

Fig. 1 Screw position was assessed on lateral radiographs as the ratio of the distance from the center of the screw to the dorsal (D) and volar (V) cortices. Ratio = D/V.

($p = 0.007$). Postoperative grip strength averaged 70% of the contralateral side (range: 40–100%). Mean wrist range of motion decreased postoperatively in all planes. The mean wrist flexion decreased from 63.3 degrees (range: 40–75) to 39.5 degrees (range: 15–75), and the mean wrist extension decreased from 61.5 degrees (range: 30–75) to 50.7 degrees (range: 20–75). Similarly, the mean radial deviation decreased from 18.7 degrees (range: 0–30) to 15.4 degrees (range: 8–30), and the mean ulnar deviation decreased from 33.6 degrees (range: 15–45) to 25.4 degrees (range: 13–45) (►**Table 1**).

Radiographic Outcomes

The mean preoperative static SL interval and SL angle measured 4 mm (range: 1.1–7) and 54 degrees (range: 31.8–88.9), respectively. On the immediate postoperative static radiographs, the mean SL interval was 1.7 mm (range: 0.8–2.8) and the mean SL angle was 43.3 degrees (range: 33.5–58.7). The SL interval widened at the final radiographic follow-up in seven wrists (►**Table 2**). The final SL interval and SL angle measured 2.6 mm (range: 1– 4.9) and 51.5 degrees (range: 25–73), respectively. The mean SL interval for the open and arthroscopically assisted technique was the same at 2.6 mm, whereas the mean postoperative SL angle was 49.9 and 56.1 degrees for the open and arthroscopically assisted techniques, respectively (►**Table 1**).

Seven (58%) wrists developed progressive degenerative changes, with stage II SLAC disease noted in five (45%) wrists and stage III disease noted in two (18%) wrists. Two of these underwent an arthroscopically assisted technique, whereas five underwent an open technique. The remaining five (42%) wrists were deemed to be a radiographic success based on the definition by Larson and Stern.

Screw placement varied significantly in this cohort with a mean dorsal-to-volar ratio of 1.4 (range: 0.36–3.2). There was no correlation between the position of the screw and any clinical, functional, or radiographic outcomes in this cohort ($p > 0.05$).

Table 2 Complications following RASL procedure

Complications	Screw type	Technical error
Screw migration	TwinFix	Screw too short
Widened SL interval Progressive SLAC (stage II)	Herbert/Whipple	None
Widened SL interval Progressive SLAC (stage II)	Herbert/Whipple	Screw too short
Widened SL interval Progressive SLAC (stage I)	TriMed	Screw too short
Widened SL interval Progressive SLAC (stage III)	TriMed	Poor screw trajectory
Widened SL interval Progressive SLAC (stage II)	TriMed	Screw too short
Widened SL interval Progressive SLAC (stage III)	Herbert/Whipple	None
Widened SL interval Progressive SLAC (stage II)	TriMed	Poor screw trajectory

Abbreviations: RASL, reduction and association of the scaphoid and lunate; SL, scapholunate; SLAC, scapholunate advanced collapse.

Functional Outcomes

The Mayo Wrist Score at the final follow-up was borderline poor with a mean score of 63.3 (range: 40–95). The only excellent outcome was in a patient with Geissler stage III disease. The mean Mayo Wrist Scores for wrists with radiographic success was 75 (range: 60–95), whereas for those deemed to be radiographic failures, the mean score was 55 (range: 40–70) ($p = 0.03$) (►**Table 1**). Five patients were unable to return to their prior or desired level of activity following the RASL procedure. Interestingly, two patients were able to return to law enforcement and fire a gun with surgery performed on their dominant trigger hand despite widening of the SL interval at the final radiographic follow-up. One patient with only 7 months of clinical and radiographic follow-up was able to return to full contact in professional American football. This patient was unavailable for further follow-up.

DASH scores were available for eight patients, with a mean of 12.6 (range: 0–24). The four patients without DASH scores included a patient with persistent pain following a four-corner fusion requiring a pisiform excision, a patient with radiocarpal arthritis following a modified Brunelli reconstruction treated with intra-articular corticosteroid injections, a patient with persistent pain following screw removal being treated as part of a Workers' Compensation claim, and a professional athlete noted.

Complications and Reoperations

Worsening of the preoperative SL diastasis was noted in one (8%) wrist. Six (50%) patients, however, were noted to have progressive SL gap widening from their immediate postoperative radiographs compared with their final result demonstrating failure to maintain the intraoperative reduction. Seven (58%) of patients had worsening degenerative changes. These complications are summarized in ►**Table 2.**

A technical error is noted in six (50%) cases with either the screw being too short or the trajectory of the screw, particularly in the coronal plane, being suboptimal. Those with poor trajectory did not have a radial styloidectomy performed. Progressive painful screw lucencies were noted in eight (67%) wrists. There were a total of 10 (83%) reoperations in this cohort. Eight wrists required screw removal for progressive osteolysis and pain at a mean of 9.2 months postoperatively (range: 1–24 months) (►Fig. 2). One patient underwent screw removal at 1 month postoperatively due to significant early loss of reduction, unremitting pain, and radiographic evidence of screw migration. The patient's Mayo Wrist Score was 50. He developed progressive SLAC changes but was able to continue working in law enforcement. Two (18%) other wrists underwent a salvage four-corner fusion at 4 and 10 months, respectively. One patient underwent a modified Brunelli 9 months after screw removal (►Table 3).

Discussion

Management of chronic SL instability presents a particular challenge to surgeons as outcomes of various techniques have been inconsistent.[15] Rosenwasser et al reported on 32 patients who underwent the RASL procedure and noted that only 2 patients required salvage procedures for progressive degenerative changes.[8] The authors noted maintenance of

Fig. 2 Posterioranterior radiograph demonstrating a lucency around a TwinFix (Stryker, Kalamazoo, MI) screw. The screw was noted to be too short and did not engaged the radial scaphoid cortex. The surrounding bone appeared to be jeopardized due to the windshield wiper effect of the screw. This patient had pain and underwent screw removal.

the radiographic reduction of the scaphoid and lunate. With the goal of creating a pseudoarthrosis, there is preserved motion between the scaphoid and the lunate about the screw. As the wrist moves through planes of motion, there is rotation, translation, flexion–extension, and radioulnar deviation that occur, which could theoretically cause a high rate of loosening of the implant.[16,17]

Larson and Stern reported on eight wrists that underwent the open RASL procedure at a mean follow-up of 38 months.[11] The authors noted that 50% of wrists required screw removal for progressive lucency. The authors noted that one patient had progression to SLAC wrist but did not undergo further operative intervention. Our study demonstrates a slightly higher rate of screw lucency at 67%, with two patients requiring a salvage procedure. Additionally, Larson and Stern reported that the SL interval increased over time from the initial postoperative radiographs. This occurred in our series but to a lesser degree.

Three patients in our series underwent an arthroscopically assisted RASL procedure as described by Aviles et al.[10] All three underwent screw removal, with one patient developing persistent pain and instability for which a modified Brunelli procedure was performed.[2] At the final follow-up, the patient returned to work with limitations, grip strength was 53% of the contralateral wrist, and range of motion was limited to 50-degree extension and 35-degree flexion. Cognet et al reported on seven patients that underwent the arthroscopically assisted RASL, with all seven wrists requiring screw removal.[13] Four of their patients required further salvage procedure as well.

Caloia et al reported on nine wrists that underwent the arthroscopically assisted RASL procedure noting decreased VAS for pain and improved SL angles.[12] Three (33%) wrists in their series required screw removal for progressive loosening. The authors describe the ideal position of the implant through the central axis of the joint. We attempted to quantify the effect of screw placement on outcomes. Given the wide range of screw placement in our series combined with the small sample size, no definitive conclusions could be confidently ascertained. Rosenwasser et al recommended that the Herbert type screw be placed within the central portion and axis of both the scaphoid and the lunate.[8] The screw should also be of appropriate length to have threads across the SL articulation while still engaging the radial scaphoid cortex.

More recently, Koehler et al reported on 18 patients who underwent the arthroscopically assisted RASL at a mean follow-up of 36 months.[14] The authors noted that patients with a preoperative SL interval greater than 5 mm and arthritic changes between the scaphoid and radial styloid were at a greater risk of complications or failure. In our small series, three patients had a preoperative SL interval greater than 5 mm, two of which went on to have SL interval widening with symptomatic screw osteolysis requiring hardware removal. Our cohort had only one patient with SLAC stage I disease preoperatively. This patient went on to have persistent pain and underwent a salvage four-corner arthrodesis.

Koehler et al also attempted to describe the optimal technical considerations of the RASL procedure.[14] First, screw length and position was reviewed. They surmised

Table 3 Reoperation patient data

Patient	Gender	Age	Geissler stage	Technique	Screw position (ratio = D/V)	Postoperative SLAC stage	Reoperation 1	Time to reoperation (months)	Reoperation 2
1	M	22	III	Open	2.21	–	–	–	–
2	M	26	IV	Open	0.36	–	–	–	–
3	M	62	–	Open	3.22	III	Screw removal	24	–
4	M	39	IV	Open	1.22	II	Screw removal	4	–
5	F	18	III	Open	0.53	–	Screw removal	7	–
6	M	46	IV	Open	0.60	III	Screw removal	1	–
7	M	41	IV	Open	1.60	II	Screw removal	23	–
8	M	41	–	Open	0.50	II	Four-corner fusion	4	–
9	M	17	IV	Open	2.88	–	Screw removal	8	–
10	F	53	IV	Arthroscopic	0.92	II	Four-corner fusion	10	Pisiform excision
11	F	25	IV	Arthroscopic	0.80	–	Screw removal	3	–
12	F	28	IV	Arthroscopic	2.44	II	Screw removal	4	Modified Brunelli

Abbreviations: D/V, dorsal/volar; SLAC, scapholunate advanced collapse.

that leaving one to two threads in the scaphoid cortex improved outcomes, thus requiring a longer screw. Four (50%) of our complications occurred with screws that would be considered too short and did not engage the scaphoid cortex. Based on these data, we can recommend that to decrease the risk of failure, the screw should be long enough. The authors further suggested that placement of the screw in the volar pole of the lunate along the proximal-ulnar corner provided the best fixation. In our review of eight complications, the screw position within the lunate on the lateral radiograph was highly variable, and half were noted to be in the dorsal half whereas the others were noted to be in the volar half. Based on our series, we do not have data to support this claim by Koehler et al.

As such, the retrospective study design and small sample size with limited clinical follow-up are notable limitations of our study. One patient in our cohort had less than 12 months of follow-up. At the final radiographic follow-up, this patient had no pain, returned to his desired level of activity, had maintenance of his reduction, and had no progression of SLAC arthritis. Nonetheless, there is a high rate of radiographic failure with a significant need for reoperation in our series. This is similar to other small series in the literature.[11–14] We speculate that preservation of motion across an implant will invariably lead to osteolysis and loosening. A loose implant is a known cause of pain.

Despite this, long-term functional outcomes as reported by DASH scores are reasonable, with limited disability. Patients report being satisfied. Perhaps surgeons should counsel patients on the need for screw removal or plan for this as a scheduled staged procedure once a pseudoarthrosis between the scaphoid and lunate has formed. Additionally, counseling patients regarding the risk of progressive degenerative changes and future need for possible arthrodesis should be performed.

Varied results in the literature, particularly those described by Rosenwasser et al, may be related to the precision and accuracy of screw placement. A larger radiographic study assessing the position of the screw across the SL articulation may provide insight into the successes and failures of this procedure. Future studies should also standardize technique variables including screw type, use of radial styloidectomy, and open or arthroscopic approaches. Based on our data, poor screw trajectory and use of too short a screw were associated with complications. Standardizing a radial styloidectomy, as mentioned in the original description of the procedure, may optimize trajectory.

In conclusion, this study showed that although the RASL procedure improved the radiographic SL widening, there was a high rate of failure and reoperation. Based on the sample size, variables in technique, and variation in screw position on the lateral radiograph, this study is unable to elucidate the factors that may provide optimal results with this procedure. Additionally, the technical failures in this study may be related to the challenges of precise screw placement and expertise required to perform the RASL procedure rather than failures of the procedure itself. Nonetheless, due to the high rate of early failures and need for reoperation, the senior author (B. T. E.) no longer favors this procedure.

Note
This work was performed at the Mayo Clinic, Rochester, MN.

Ethical Approval
This study underwent Institutional Review Board (IRB) approval by an internal ethical committee approving the study (IRB number: 15–002433).

Conflict of Interest
None.

References

1 Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am 1984;9 (03):358–365

2 Garcia-Elias M, Lluch AL, Stanley JK. Three-ligament tenodesis for the treatment of scapholunate dissociation: indications and surgical technique. J Hand Surg Am 2006;31(01):125–134

3 Links AC, Chin SH, Waitayawinyu T, Trumble TE. Scapholunate interosseous ligament reconstruction: results with a modified Brunelli technique versus four-bone weave. J Hand Surg Am 2008; 33(06):850–856

4 Szabo RM, Slater RR Jr, Palumbo CF, Gerlach T. Dorsal intercarpal ligament capsulodesis for chronic, static scapholunate dissocia- tion: clinical results. J Hand Surg Am 2002;27(06):978–984

5 Moran SL, Cooney WP, Berger RA, Strickland J. Capsulodesis for the treatment of chronic scapholunate instability. J Hand Surg Am 2005;30(01):16–23

6 Kleinman WB, Carroll C IV. Scapho-trapezio-trapezoid arthrod- esis for treatment of chronic static and dynamic scapho-lunate instability: a 10-year perspective on pitfalls and complications. J Hand Surg Am 1990;15(03):408–414

7 Watson HK, Ryu J, Akelman E. Limited triscaphoid intercarpal arthrodesis for rotatory subluxation of the scaphoid. J Bone Joint Surg Am 1986;68(03):345–349

8 Rosenwasser MP, Miyasajsa KC, Strauch RJ. The RASL procedure: reduction and association of the scaphoid and lunate using the Herbert screw. Tech Hand Up Extrem Surg 1997;1(04):263–272

9 White NJ, Raskolnikov D, Swart E, Rosenwasser MP. Reduction and association of the scaphoid and lunate (RASL): long-term follow-up of a reconstruction technique for chronic scapholu- nate dissociation. J Hand Surg Am 2010;35(10):16–17

10 Aviles AJ, Lee SK, Hausman MR. Arthroscopic reduction-association of the scapholunate. Arthroscopy 2007;23(01):105.e1–105.e5

11 Larson TB, Stern PJ. Reduction and association of the scaphoid and lunate procedure: short-term clinical and radiographic outcomes. J Hand Surg Am 2014;39(11):2168–2174

12 Caloia M, Caloia H, Pereira E. Arthroscopic scapholunate joint reduction. Is an effective treatment for irreparable scapho- lunate ligament tears? Clin Orthop Relat Res 2012;470(04): 972–978

13 Cognet JM, Levadoux M, Martinache X. The use of screws in the treatment of scapholunate instability. J Hand Surg Eur Vol 2011; 36(08):690–693

14 Koehler SM, Guerra SM, Kim JM, Sakamoto S, Lovy AJ, Hausman MR. Outcome of arthroscopic reduction association of the scapholunate joint. J Hand Surg Eur Vol 2016;41(01):48–55

15 Manuel J, Moran SL. The diagnosis and treatment of scapholunate instability. Hand Clin 2010;26(01):129–144

16 Kobayashi M, Berger RA, Nagy L, et al. Normal kinematics of carpal bones: a three-dimensional analysis of carpal bone motion rela- tive to the radius. J Biomech 1997;30(08):787–793

17 Ruby LK, Cooney WP III, An KN, Linscheid RL, Chao EY. Relative motion of selected carpal bones: a kinematic analysis of the normal wrist. J Hand Surg Am 1988;13(01):1–10